Early life history of the introduced seastar *Asterias amurensis* in the Derwent estuary, Tasmania: The potential for ecology-based management

Alice E. Morris (BSc. Hons)

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School of Zoology, University of Tasmania (April 2002)

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Abstract

The early life-history of the introduced Northern Pacific seastar (*Asterias amurensis)* in the Derwent Estuary, Tasmania, is investigated with an aim to identify opportunities for improved management. A discrete non-equilibrium model of gamete dispersal and fertilization success is developed. The model is parameterized with species-specific gamete traits measured in the estuary population, and is validated using empirically determined estimates of fertilization success, which required containing gametes in collection flasks. *In situ* measurements of the proportion of eggs fertilized ranged from 0.80 ± 0.08 (SE) adjacent to the spawning male, to 0.16 ± 0.04 (SE) for separation distances of 16 m. The model is then adapted to simulate dispersal of gametes without the experimental artifact of containing gametes in flasks. There is good concordance between empirical estimates and model predictions when the model simulates the experimental procedure. However, when simulations allow for dispersal and fertilization without confinement of gametes in the collection device, predicted fertilization success is substantially lower at 0.05 adjacent to the spawning male and 0.03 at 16 m.

The model is extended to predict the reproductive potential of discrete populations of the seastar in the Derwent Estuary. The effects of population density, group size, spawning synchrony, sex ratio, and water depth on the total number of eggs fertilized and the proportion of eggs fertilized is predicted. Within the range of parameters tested, group size, density and water depth had the most significant effects on fertilization success. The model predicted a 300% increase in fertilization success when density is increased from 0.025 to 0.2 individuals m^{-2}. Spatial variability in the reproductive potential of populations in the estuary is also assessed based on gonad indices of seastars determined at 9 sites in the estuary. Gonad indices of starfish at yacht clubs were 3 times higher than 'control' and wharf sites. Given results of the gamete dispersal model, and spatial variability in density and gonad indices, it is likely that discrete populations in the Derwent Estuary contribute differentially to larval production, and particular populations might potentially be targeted for management.

Dispersal of larvae of the introduced seastar *Asterias amurensis* in the Derwent Estuary, and advection of larvae out of the estuary, is predicted using an

inverse transport model incorporating the behavioural responses of larvae at different stages of development to salinity and light. In laboratory conditions larvae demonstrate reverse diel migration, and do not swim into water < 26 ppt salinity. This behaviour influenced the predicted mortality and retention of larvae in the Derwent Estuary. However, regardless of the swimming behaviour, the transport model suggests that the majority (> 99%) of late-stage larvae are advected out of the estuary.

Substrata that induce settlement and metamorphosis of laboratory reared larvae were determined by introducing competent brachiolaria into wells containing substrata commonly available in SE Tasmania. Larvae settled at high rates when exposed to non-geniculate coralline algae (0.98 ± 0.02 SE after 2 days) and at moderate rates on mud and bare rock (0.37 ± 0.06 and 0.44 ± 0.06 respectively after 7 days). On day 7, larval settlement on sand and in the control (filtered seawater) were low (0.01 ± 0.01 and 0.05 ± 0.02 respectively). Based on the distribution of these substrata in the Derwent Estuary, these results suggest that larvae potentially settle at low rates in the lower estuary where the benthos is largely sand, and at moderate rates in the mid-estuary where fine sediments dominate. Settlement at high rates might potentially occur on fringing reefs in the mid and lower estuary, but this habitat comprises a small portion of the estuary.

Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and to the best of my knowledge, contains no material previously published or written by any other person, except where due reference has been given in the text.

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Alice Morris

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Chapter 1: Introduction

The threat of marine introductions

Over the last two decades, marine introductions have been recognised as a major threat to marine environments, marine-based industries, and human health (Carlton 1996, 1999; Carlton and Geller 1993; Hallegraeff 1998; Harvell *et al.* 1999; Lafferty and Kuris 1994, 1996; McLoughlin and Thresher 1994). Many marine invasive species are introduced as larvae through ballast water exchange (Carlton 1996; Carlton and Geller 1993; Ruiz *et al*. 2000) and arrive in the donor port without predators, pathogens or parasites (Lafferty and Kuris 1994). This lack of natural enemies can result in outbreaks of marine invaders which amplifies the impact of these species (Lafferty and Kuris 1994). *Asterias amurensis*, native to the north-west Pacific (Davenport and McLoughlin 1993; Fisher 1930), is an invasive species that has arrived in Australian waters with no parasites (Goggin 1998) and has attained high densities through population outbreak.

Asterias amurensis *in Australian waters*

Asterias amurensis was accidentally introduced into the Derwent Estuary, Tasmania in the early 1980's (Davenport and McLoughlin 1993). Since the introduction, the seastar has become prolific in the estuary, with adult densities reaching up to 9.44 individuals m^{-2} (Buttermore *et al*. 1994), and larval densities among the highest of any marine invertebrate (Bruce *et al*. 1995). The density of *A. amurensis* in the middle reaches of the estuary is higher than densities considered as outbreaks in Japan (Buttermore *et al*. 1994; Grannum *et al*. 1996; Morrice 1995; Nojima *et al*. 1986). Given the unprecedented abundance in the Derwent Estuary and the major impact of the seastar on marine-based industries within the native range (Hatanaka and Kosaka 1959; Kim 1969; Nojima *et al*. 1986) *Asterias amurensis* was identified as a target pest species by the Australian Ballast Water Management Advisory Committee (ABWMAC). Over the last decade the seastar was also introduced into Port Phillip Bay, Victoria, and the population size has escalated from 340 000 in 1998 to 75 million in 2000 (Parry and Cohen 2001). The seastar directly impacts marine based industries in Tasmania by settling in scallop spat collectors and oyster trays (Martin and Proctor 2000), and has potential to impact other marine based industries and the marine environment in southern